NOAA National Centers for Environmental Information Topo-Bathymetric Digital Elevation Modeling: Florida Keys and South Florida

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Introduction

This report briefly describes the creation of a suite of tiled Digital Elevation Models (DEMs) developed for South Florida and the Florida Keys in 2016 by the NOAA National Centers for Environmental Information (NCEI; Fig. 1). This work was funded by the National Tsunami Hazard Mitigation Program to support tsunami modeling and research.

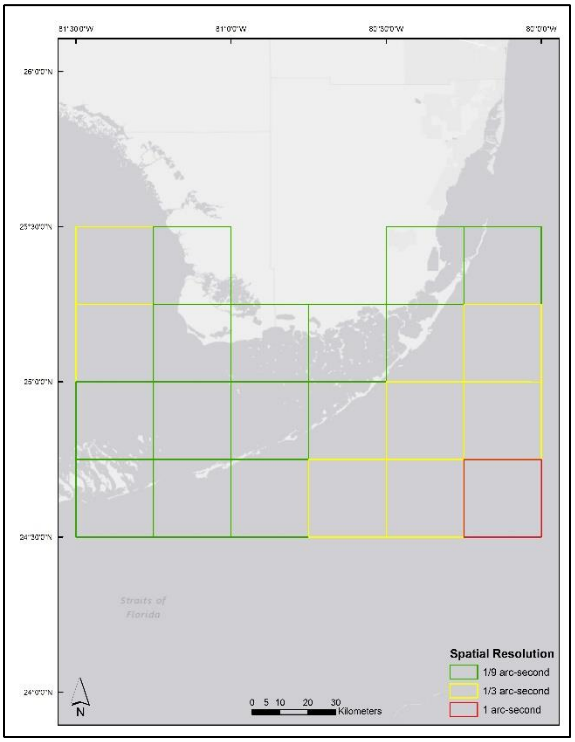


Figure 1. Spatial Extent of the 2016 NOAA NCEI Florida Keys Tiled DEM suite. Note that only 1/9 arc-second DEM tiles integrate topography and bathymetry.

The DEMs have been built according to specifications developed jointly by NOAA NCEI and the United States Geological Survey (USGS) to help better define a consistent elevation mapping framework for the nation (Eakins et al., 2015; Table 1). Overall, 22 tiled DEMs were created in the area of interest: 14 tiles were created at the highest resolution of 1/9 arc-seconds, 7 were created at a resolution of 1/3 arc-seconds and 1 tile was created at a resolution of 1 arc-second. Only 1/9 arc-second DEMS tiles integrate topography and bathymetry. The DEM tiles represent best available data at the time of their creation; the intent is to update specific tiles as new source data becomes available. The utilization of a tiling scheme in developing the DEMs is intended to improve data management during source data processing as well as facilitate targeted DEM updates.

Table 1. DEM specifications of the Florida Keys Tiled DEM suite (from Eakins et al., 2015)

Projection	Local UTM Zone		Geographic				
Cell size	1 m	3 m	1/9 arc-sec	1/3 arc-sec	1 arc-sec	3 arc-sec	9 arc-sec
Offshore coverage	1 nm	3 nm	3 nm	24 nm	500-m depth	200 nm	ECS, LMEs
Grid registration	Pixel						
Horizontal datum	NAD 83						
Vertical datum	NAVD 88				Sea level		
Edge precision	3 m		0.01 degrees (36 arc-sec)				
Elevation precision	0.01 m	0.1 m				1 m	
Multi-temporal	yes		No				
Surface type	Bare earth						
Restrictions	None/Public						

The final integrated 1/9 arc-second topography-bathymetry DEM tiles and 1/3 arc-second bathymetry tiles are referenced to the North American Vertical Datum of 1988. The lone 1 arc-second bathymetry tile is referenced to an assumed Mean Sea Level.

Data Processing

Original source topographic and bathymetric data were collected by a variety of agencies, including federal, state and local governments as well as academia. Source data were obtained in a variety of different formats and referenced to disparate horizontal and vertical datums (Table 2).

Table 2. Source datasets used in the creation of the NOAA NCEI Florida Keys Tiled DEM suite

Source Dataset	Data Type	Acquisition Date	Horizontal Datum/Projection	Vertical Datum
Florida Department of Emergency Management Lidar (gridded topography available via USGS National Map)	Topographic Lidar (gridded)	2007-2008	NAD83	NAVD88 (geoid 03)
NOAA National Geodetic Survey Topographic-Bathymetric Lidar	Topographic-Bathymetric Lidar	2014	NAD83	NAVD88 (geoid 12b)
Florida Fish and Wildlife Research Institute Biscayne Bay Bathymetric Lidar	Bathymetric Lidar (gridded)	2008	NAD83	NAVD88 (geoid03)
NOAA National Ocean Service Hydrographic Survey Data	Bathymetric soundings and gridded bathymetry	1885-2009	NAD83	MLW/MLLW
USGS High-Resolution Bathymetry	Singlebeam bathymetry soundings	1990	NAD83	NAVD88
NOAA NCEI Multibeam Database (see Appendix I for list of specific survey ID's)	Multibeam bathymetry soundings	1990-2014	WGS84	Instantaneous Water Level

All source data were converted to a common horizontal of North American Datum of 1983 using a combination of various Geospatial Data Abstract Libraries (GDAL) utilities (using spatial reference information defined by various codes maintained by the European Petroleum Survey Group (EPSG)) and the NOAA VDatum software utility, depending on the dataset in question.

The vertical datum of bathymetric datasets referenced to Mean Lower Low Water (MLLW) were converted to the North American Datum of 1988 (NAVD88; Geoid12A definition) for consistency with topographic data already referenced to NAVD88. No conversion occurred among topographic datasets referenced to different realizations of NAVD88 (i.e. defined by different geoid models). Various locations in the study area were tested to determine if such a conversion was warranted. The results deemed this to be unnecessary, as the magnitude of these differences was on the order of millimeters (Figure 2). Multibeam bathymetry, which in most cases was obtained uncorrected with regard to the water level at the time of data acquisition, was left as such. The magnitude of the differences between various tidal datums and NAVD88 was assumed to be well within the measurement uncertainty associated with the multibeam data (Appendix II).

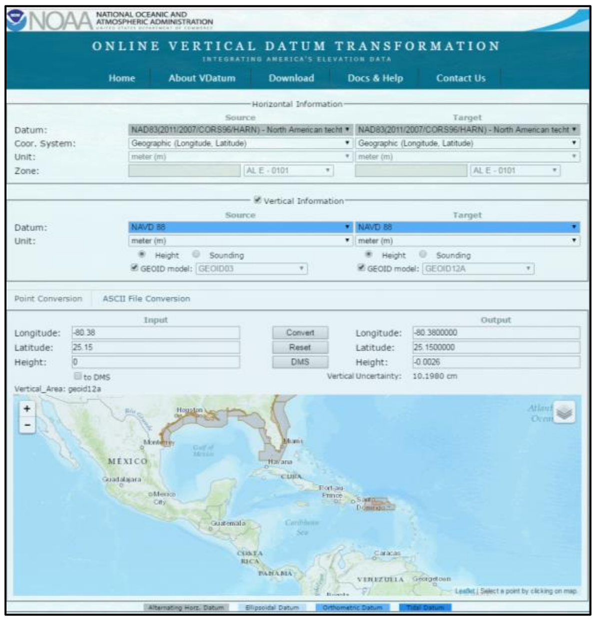


Figure 2. An example of the magnitude of difference between definitions of NAVD88 in the study area.

All data were converted to a common data format (ASCII xyz) in preparation for gridding. If a dataset was obtained in a raster format, it was resampled using a bilinear resampling algorithm to match the target spatial resolution of the affected tile, then converted to ASCII xyz using GDAL. All data was reviewed and evaluated for internal and external consistency with adjacent data. Anomalies in were removed through visual inspection and automated filtering.

MB-System's 'mb-grid' utility was used for all gridding processes. A tensioned thin-plate spline algorithm was used to interpolate depth values in pixels within the DEM extent that were unconstrained by elevation measurements. Constrained pixels were assigned a final elevation value based on the Gaussian weighted average of the input source elevation measurements.

For all tiles, an initial bathymetric surface was created using the source bathymetry (See Carignan et al., 2011 for a detailed description of the process). Given the disparate nature of the source bathymetric data, a low-pass median filter (5x5 kernel) was applied to each bathymetric surface in order to minimize offsets among adjacent datasets.

For tiles that did not integrate bathymetry and topography, the smoothed bathymetric surface is the final product. In cases where both bathymetry and topography are mapped, the smoothed bathymetric surface was mosaicked with gridded topography in order to create a seamless bathy-topo elevation surface. It must be noted that in these cases, the bathymetric surface was initially gridded at a spatial resolution of 1/3 arc-seconds, then resampled to the target resolution of 1/9 arc-seconds. A constraint was imposed on the bathymetric surface, such that the maximum depth value was -0.305 meters. This was performed in order to ensure areas of submerged topography (i.e. bathymetry) maintained depth values below MLLW.

Final DEM tiles were qualitatively evaluated to identify anomalous data points, as well as compared with imagery and NOAA Raster Nautical Charts. If necessary, persistent anomalies were cleaned from the input source data and the DEM tile was re-generated using the previously described processes. No quantitative analysis was performed to assess the accuracy of the DEMs, although this continues to be an area of active research at NCEI (see Amante and Eakins, 2016).

For more information, contact dem.info@noaa.gov

References:

Amante, C.J. and Eakins, B.W., 2016. Accuracy of interpolated bathymetry in digital elevation models. *In*: Brock, J.C., Gesch, D.B., Parrish, C.E., Rogers, J.N., and Wright, C.W. (eds.), *Advances in Topobathymetric Mapping, Models and Applications. Journal of Coastal Research*, Special Issue, No. 76, pp.122-133.

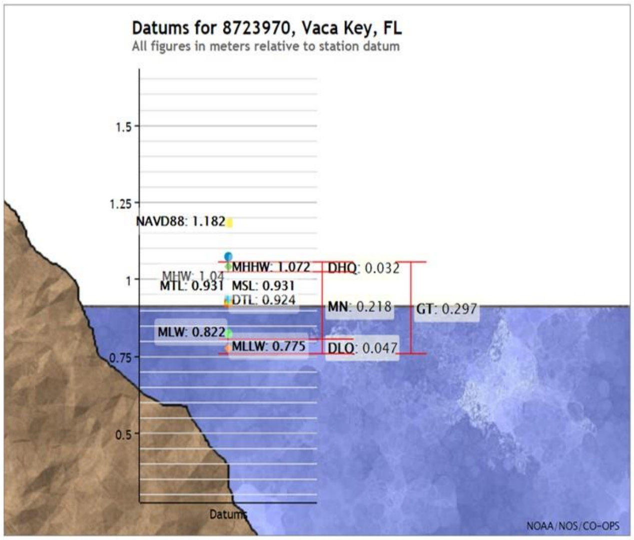
Carignan, K.S.; Taylor, L.A.; Eakins, B.W.; Caldwell, R.J; Friday, D.Z.; Grothe, P.R. and Lim, E., 2011. Digital Elevation Models of Central California and San Francisco Bay: Procedures, Data Sources and Analysis. *NOAA Technical Memorandum NESDIS NGDC-52*, 49p.

B.W. Eakins, Danielson, J.J., Sutherland, M.G., McLean, S.J., 2015. A framework for a seamless depiction of merged bathymetry and topography along U.S. coasts. *Proceedings of the U.S. Hydro Conference* (National Harbor, MD, March 16-19), 10p.

Appendix I – List of multibeam sonar surveys used in the creation of the Florida Keys DEMs

Survey ID	Year	Ship
AT29-03	2015	Atlantis
EX1402L1	2014	Okeanos Explorer
EX1403	2014	Okeanos Explorer
FK007	2013	Falkor
MGL1304	2013	Marcus G. Langseth
NF-13-10T	2013	Nancy Foster
EX1202Leg1	2012	Okeanos Explorer
EX1203	2012	Okeanos Explorer
EX1106	2011	Okeanos Explorer
NF-11-09-CIOERT	2011	Nancy Foster
LCE2010	2010	Lost Coast Explorer
RB1008	2010	Ronald H. Brown
NF-09-09-FKNMS	2009	Nancy Foster
KNOX20RR	2008	Roger Revelle
NF-08-12-FKNMS	2008	Nancy Foster
NF-07-14-FKNMS	2007	Nancy Foster
KM0201	2002	Kilo Moana
KN166L02	2002	Knorr
USF2000	2000	Bellows
USF1999	1999	Bellows
EW9701A	1997	Maurice Ewing
EW9609	1996	Maurice Ewing
EW9001	1990	Maurice Ewing

Appendix II – Schematic of measured vertical datum offsets at NOAA tide gauge 8723970



Elevations on Station Datum

Station: 8723970, Vaca Key, FL
T.M.: 75
Status: Accepted (Sep 26 2011)
Epoch: 1983-2001
Units: Meters
Datum: STND

Datum	Value	Description
MHHW	1.072	Mean Higher-High Water
MHW	1.040	Mean High Water
MTL	0.931	Mean Tide Level
MSL	0.931	Mean Sea Level
DTL	0.924	Mean Diurnal Tide Level
MLW	0.822	Mean Low Water
MLLW	0.775	Mean Lower-Low Water
NAVD88	1.182	North American Vertical Datum of 1988
STND	0.000	Station Datum
GT	0.297	Great Diurnal Range
MN	0.218	Mean Range of Tide
DHQ	0.032	Mean Diurnal High Water Inequality
DLQ	0.047	Mean Diurnal Low Water Inequality